DISCUSSIONS

CLEANING WATER MAINS

I have enjoyed reading Mr. Foreman's paper,[1] particularly as he has told the bright side of cleaning. At Charleston, S. C. we have a twenty-four inch main 55,000 feet long. It was cleaned first early in 1916 and again in 1917, and last December we again made a test to determine the friction losses. We have a twenty-inch line paralleling the twenty-four inch line for 30,000 feet of its length. We used the twenty-inch line as piezometric pipe, measuring the water passing through the twenty-four inch line by a Simplex Venturi Type meter. The test to determine the friction loss covered the lengths of 10,000, 20,000 and 30,000 feet. The results obtained showed that the co-efficient in Chezy's formula had fallen to 76.

We at once entered into a contract to clean the main and the work was done in April of this year. Tests made immediately after cleaning showed that the co-efficient had been restored to 106. Knowing that the main had, after former cleaning, deteriorated more or less, and the co-efficient had fallen from something over 100 in 1917 to 76 in 1920, we decided that we would make monthly observations in an effort to determine the rapidity of deterioration. The test immediately after cleaning was made on April 18th, the second test was made on May 19th, and to our great surprise we found that the co-efficient had dropped to 80. A third test made on June 28th indicated that the co-efficient was $79\frac{1}{2}$, substantially the same as the test in May and certainly within the error of observation.

An examination of the inside wall of the main showed that the entire surface was covered with small tubercles from $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter, and projecting from the surface anywhere from $\frac{1}{32}$ to $\frac{1}{8}$ of an inch. Probably the best illustration is that of the pebble dash on a stucco wall. From this indication and our general observation we are of the opinion that the size or the reduction in the area of the pipe, due to the tubercles, is not of so great importance as the number and the result in the increase in the roughness of the interior of the pipe.

[1] JOURNAL, July, 1921, page 369.

Our water supply is obtained from a tidal estuary of the Cooper River, the storage reservoir being formed by a dam which acts to cut off the tidal salt water. The water is very soft and highly colored having an alkalinity of about eleven parts per million. After coagulation and filtration we add alkalinity in the form of lime water to bring the alkalinity of the filtered water up to 18-20 parts per million. This is necessary to avoid the red water troubles so often found in filtered waters.

J. E. Gibson.[2]

When I first learned that Mr. Foreman had prepared this paper for the Association it seemed inadvisable for me to discuss it, since I am interested in the Company which does the cleaning work, but after reading Mr. Gibson's statement, I thought that some one might reason from this particular and isolated case, and arrive at an erroneous conclusion.

Many hundreds of miles of pipe have been cleaned in the United States in the past fifteen years, and some have been re-cleaned, but the percentage of re-cleaned mains is very small.

Now in many instances, main cleaning was an absolute necessity and if such mains had become rapidly incrusted after cleaning, there would have been a much larger percentage of re-cleaning. The condition as described in Charleston is by far the worst that has come to my attention, and I believe upon further investigation would be found not to be in any way a result of either the original cleaning, or re-cleaning, operations. Possibly treatment of the water at small cost would retard or even prevent this action of the water, but that, of course, would be a question for the experienced engineer on water treatment to decide.

I can mention specifically the following places where water main cleaning has been extensively employed and regarding which definite information has been given me. While for the first year after cleaning the water action may have been noticeably greater, the incrusting or corrosive action after that time was no worse than in pipes which had never been cleaned. These cities are Cincinnati, O., Buffalo, N. Y., Boston, Mass., Cambridge, Mass., Shreveport, La., Kansas City, Kansas, and Omaha, Nebraska.

Burt B. Hodgman.[3]

[2] Manager and Engineer, Water Department, Charleston, S. C.

[3] Civil Engineer, 50 Church St., New York, N. Y.

STORAGE OF WATER

To quote from the first paragraph of Colonel Johnson's paper:[4] "In a single decade millions of people grievously suffered and hundreds of thousands died in consequence of disease brought to them by the agency of impure water." There is nothing especially dramatic about the onset of typhoid fever. Even during periods of epidemic the disease is looked upon, seriously doubtless, but without any approach to panic. Stress is wisely laid upon the fever's insidious approach in Colonel Johnson's appeal for more than simple storage when a doubtful water is being prepared for municipal supply.

Suppose that in a city of a hundred thousand inhabitants some public undertaking (the much-accused trolley system, for instance) were so badly managed that 50 human lives were crushed out annually and 500 other persons were more or less seriously injured, does anyone believe that the people of the town would tolerate such a state of affairs, or that they would grudge the amount of money necessary to stop such carnage? Surely not, yet because of a faulty water supply they might be submitting quietly to just as large a loss from death and disability, only coming in a way less tangible and less shocking to the feelings.

There is no system or efficient method for purifying a polluted water so expensive but that a community can well afford to introduce it, rather than to drink the water in its raw state, and this, too, from purely economic considerations, and leaving out of sight all ethical questions whatsoever.

Public works which could eliminate a reasonable fraction of the great typhoid tax would certainly pay for themselves in the course of a few years even though they were originally expensive. Let us ask such as may have doubts upon this point to read again the history of the epidemic of typhoid fever in the valley of the Tees, and the records of the cholera plague at Hamburg, and to note what such dire experiences have taught and what use has been made of the teaching.

Do those interested in the furnishing of water to a town ever permit a factor to enter their calculations representing the pecuniary damages that might be claimed by parties who receive bodily injury

[4] JOURNAL, July, 1921, page 291.

through the use of impure water? This question appears to be taking on some magnitude, and if the courts look favorably upon it, there is scarcely a limit to the proportions it might assume.

W. P. Mason.[5]

ACID POLLUTION OF STREAMS

Prof. C. M. Young has given an exhaustive paper[6] on the river pollution occurring in Western Pennsylvania. The work done by the United States Engineer Office in 1914 was very thorough and Professor Young's paper so ably presents the facts that one can scarcely add anything thereto. As the writer has had the opportunity, however, of making a study of the conditions both in regard to the local damage and economic loss and the effects extending by way of the water courses to other parts of the State, and as the most extensive source of the pollution referred to is from coal mine operations, it may be of interest to give some additional data bearing more or less directly upon the coal industry in Pennsylvania.

At least forty-four of the total sixty-seven counties of the State contain coal, eleven in the anthracite and thirty-three in the bituminous fields. At the present time, however, ten counties in the anthracite and twenty-seven in the bituminous regions are producing coal for market.

The anthracite fields cover 315,482 acres of territory and contained originally over 57,000,000,000 tons of coal of which 94 per cent was still in place up to the year 1918.

Figures for quantities of bituminous coal are not available, but an idea of their extent may be obtained from the total area of the bituminous counties, which is 26,547 square miles or 59 per cent of the area of the whole State.

The total production of coal for the last three years in which data are available is as follows:

	1917	1918	1919
	tons	*tons*	*tons*
Anthracite	100,000,000	99,000,000	88,000,000
Bituminous	171,000,000	177,000,000	147,000,000

[5] Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y.
[6] Journal, May, 1921, page 201.

The capital invested in the industry in 1919 was something less than $700,000,000 and the total market value of the coal produced for that year was about the same figure.

Producing coal at the present time are 2572 shipping coal mines, of which 432 are anthracite and 2140 are bituminous. In addition there are 1969 other mines, employing fewer men from which the coal is hauled in "wagons."

There are also the worked out or "abandoned mines." No records are available as to the number of this class of mines, but when drainage occurs from these old workings it is usually quite acid and lasts for years.

It might here be mentioned that the drainage from the shallow so called "wagon mines" is comparatively slight and usually free from acid, so that we do not consider the "wagon mines" as a part of our problem of acid pollution in streams.

Estimates indicate that 850,000,000 gallons of water are pumped daily from the anthracite mines and 600,000,000 gallons from the bituminous.

In the anthracite fields there are some 300 breakers and washeries discharging over 40,000,000,000 gallons of water annually, carrying 10,000,000,000 tons of fine culm into the streams. Along with this also goes acids and acid salts to the amount of 4000 tons daily.

The effect of such wastes is given by a typical case of 1300 gallons per minute of water pumped, containing 29 grains per gallon of free acid and 39 grains per gallon of combined acid. This amount is equal to 1 ton per hour of storage battery acid. This can dissolve 1400 pounds of iron per day, which at 5 cents per pound amounts to $17,000 per year. It frequently costs $20,000 to repair the damage done annually by the acid water at a single coal breaker.

A glance at the state map will give an idea of the far reaching effect of the acid pollutions. In some locations it is impossible to find a stream not contaminated. Pure water has to be brought from long distances at great cost and in some cases it is not available at all.

When the water is not acid it has become neutralized chiefly by limestone and as a result it is exceedingly hard. Both the acidity and hardness are keenly felt as well in the smaller streams in the mining regions as in the larger water courses in all of the main drainage areas of the state. Professor Young has referred to the territory and water courses tributary to the Ohio River basin, but in addition our other streams also suffer. A considerable bitumi-

nous drainage reaches the Susquehanna River although the larger contribution to our eastern rivers is from the anthracite fields.

Of the 309 breakers, 260 discharge to the Susquehanna River System, 37 to the Schuylkill and 12 to the Lehigh. In other words of the anthracite pollutions, 85 per cent occurs on the Susquehanna, 10 per cent on the Schuylkill and 5 per cent on the Lehigh.

In addition to what Professor Young has said about the drainage and economic loss in the Pittsburgh Engineering District, we find that the effects are more widespread. At least 96 public water supplies in the state receive water more or less contaminated with mine drainage. The total daily consumption from these supplies is approximately 625,000,000 gallons furnished to over 3,777,000 people or 43 per cent of the entire population of the State.

The effects upon water purification plant operation, encountered in the removal of excessive turbidity, in low alkalinity, necessitating expense for the addition of lime or soda, and the extra hardness, are apparent in the burdens borne by every consumer. Reliable figures for the excessive hardness directly chargeable to acid mine drainage are not available for all plants in the state, so that it is impossible to estimate the entire damage and economic loss felt throughout the whole commonwealth. It is believed, however, by conservative thinkers to be at least $20,000,000 annually.

To solve the problem of the acid mine pollution of streams without materially adding to the price of coal, much has been done but little accomplished. People continue to take out patents for doing the work, but they do not take out the pollution. The finer sizes of coal are being saved and the modern jig tables, classifiers and hydro-separators are proving quite efficient in this work, but there is yet much to be desired.

In some cases, as the one referred to by Professor Young, the acid is neutralized and iron compounds recovered; but the resulting excessive hardness is an important problem to be solved.

The possibility of finding some of the more valuable rarer elements should not be overlooked, but beyond small quantities of manganese little success along this line has been achieved.

The problem is sufficiently important to warrant the appointment of a special commission, with a corps of technical experts, to determine the best means of treating the wastes, to develop the recovery of by-products and to suggest the legislative policy to be adopted.

F. E. Daniels.[7]

[7] Engineering Division, State Department of Health, Harrisburg, Pa.

ACID POLLUTION OF RIVER WATER

Professor Young's article[6] on "Pollution of River Water in the Pittsburgh District" is an interesting and fairly representative account of conditions which are usually found in large coal mining sections, where the mine carries sulphur in a form which is readily changed into sulphuric acid and ferrous sulphate. Tables 1 and 2 give the average composition of the river water before and after treatment at the works of the National Tube Company, located on the south-east bank of the Monongahela River just below the junction with the Youghiogheny River. The damage caused by the excess acid in the water is, of course, a serious matter. Some of the statements of damage are, however, not due entirely to the presence of the acid in the water and would occur in any case. For instance, on page 211, Professor Young refers to the corrosion of locomotive tubes. At our McKeesport plant, we use alkaline treated water for both the locomotive and stationary boilers. In the stationary boilers, we have had no serious trouble with the tubes for ten years on account of pitting, but the locomotive tubes are often greatly damaged on account of corrosion inside of two years, the difference in this case being due to the large amount of oxygen in the locomotive

TABLE 1

Analysis of Monongahela River water—1920. Grains per gallon

	Acidity	$CaSO_4$	$MgSO_4$	SiO_2	R_2O_3	Total solids	Volatile matter	Chlorine	SO_3	CO_2 constant
January	1.50	3.99	1.89	2.38	1.13	14.81	3.49	0.20	5.10	0.3
February	1.60	4.39	2.07	1.89	1.28	20.46	3.32	0.24	5.83	0.3
March	1.00	3.18	1.57	3.66	1.49	14.58	2.50	0.22	3.84	0.3
April	0.80	3.33	1.79	1.67	1.11	11.08	2.04	0.27	4.06	0.3
May	1.00	3.75	1.77	0.86	0.86	11.78	3.03	0.28	4.59	0.3
June	0.70	4.53	1.95	2.27	1.17	15.39	3.55	0.42	4.93	0.3
July	1.00	5.80	2.47	0.63	0.51	13.41	3.67	0.44	5.32	0.3
August	0.90	4.56	1.98	0.87	0.55	12.30	2.16	0.45	5.27	0.3
September	1.70	6.77	2.84	0.65	0.70	16.50	2.68	0.54	8.60	0.3
October	2.30	8.67	3.63	0.45	1.28	23.38	2.08	0.88	11.10	0.3
November	1.50	6.34	2.64	0.70	0.80	18.36	3.03	0.61	8.19	0.3
December	1.00	3.23	1.93	0.83	0.83	11.08	2.39	0.30	4.24	0.3
Average	1.25	4.88	2.20	1.40	0.99	15.26	3.00	0.40	5.92	0.3

water where open feed water heaters are not used, which in the case of the stationary boilers remove three-fourths of the dissolved oxygen. With untreated river water the results with locomotives have been worse, of course, but most of the damage even in this case is due not so much to the acidity of water as to the combination of the acidity and free oxygen.

In large buildings in New York City the hot water supply pipes and hot water heaters are seriously corroded in six or seven years,

TABLE 2

Analysis of purified boiler water—1920. Grains per gallon

	Alkalinity				$CaSO_4$	$MgSO_4$	SiO_2	R_2O_3	Total solids	Volatile matter	Chlorine	SO_3
	P.	M.O.	CO_3	OH								
January	1.9	3.0	2.2	0.8	0.71	0.50	0.41	0.17	16.67	2.79	0.23	4.85
February	1.9	3.0	2.2	0.8	0.64	0.32	0.48	0.28	20.93	4.95	0.32	5.57
March	2.0	3.2	2.4	0.8	0.52	0.29	0.51	0.28	14.05	1.75	0.27	3.07
April	1.8	3.0	2.4	0.6	0.75	0.33	0.48	0.26	13.41	1.17	0.29	4.03
May	1.1	2.0	1.8	0.2	1.42	0.61	0.34	0.38	12.13	1.86	0.26	4.47
June	1.8	3.0	2.4	0.6	0.92	0.49	0.55	0.40	14.34	1.11	0.46	4.94
July	1.8	3.0	2.4	0.6	1.42	0.74	0.51	0.29	18.42	2.62	0.47	5.36
August	2.0	3.3	2.6	0.7	0.88	0.49	0.60	0.29	16.56	1.81	0.48	5.44
September	1.7	2.9	2.4	0.5	0.95	0.34	0.57	0.17	23.15	3.79	0.59	7.89
October	1.5	2.5	2.0	0.5	0.99	0.46	0.47	0.20	26.99	3.50	0.90	9.86
November	1.7	2.8	2.2	0.6	0.79	0.40	0.57	0.23	25.30	3.76	0.72	9.02
December	1.7	2.8	2.2	0.6	0.81	0.57	0.47	0.31	14.45	1.81	0.33	3.92
Average	1.74	2.88	2.26	0.6	0.90	0.46	0.50	0.27	18.03	2.58	0.44	5.70

P = Phenolphthalein.
M. O. = Methyl orange.
CO_3 = Normal carbonate alkalinity.
OH = Hydrate alkalinity.

although New York City water carries no sulphates or mineral acids and is considered a very pure water in every respect. In Pittsburgh the water has somewhat less action on the hot water piping than in New York City, although the water has occasional periods of acidity. The Pittsburgh water is probably more active on the piping since the filtration plant was put into operation as there is now no sediment to collect on the inside of the pipe, which formerly offered mechanical protection from corrosion. As a rule the most corrosive waters are the purest waters, which are apt to carry more dissolved oxygen.

The domestic supply from the Allegheny River is better than water from the Monongahela River, the latter below McKeesport being used more generally for cooling purposes in the mills.

Professor Young's estimate of the amount of acid dumped into the rivers from the mills in this district seems rather high, measured from our experience. On page 207, he states that fifteen tube mills use 200 tons of sulphuric acid per day. We operate one of the largest of these mills and use, when operating full, about 6 tons per day.

These conditions, largely caused by the acid mine drainage running into the rivers, are however, certainly bad enough. This Company has been trying for various reasons to economize on the use of acids. Several schemes have been tried out to recover the acid from the waste pickle, but more progress has been made by removing a large portion of the mill scale from pipe mechanically instead of depending entirely on the pickling of the surface with acid. By the installation of a considerable amount of new finishing machinery for the removal of mill scale we have been able to save about 50 per cent of the acid used in pickling pipe for galvanizing.

F. N. Speller.[8]

EFFECTIVE DILUTION AS A POLLUTION UNIT

The paper on "Effective Dilution as a Pollution Unit"[9] by Mr. W. F. Wells is of noteworthy importance and deserves careful attention by scientific persons concerned with the study and control of the pollution of water. It is extremely unfortunate that the subject of the paper was so greatly misunderstood by Colonel Johnson in his severe and unmerited criticism,[10] which may tend to obscure and befog the valuable and constructive idea that Mr. Wells has brought forth. For the significance of this idea may well be no less than to alter prevailing methods of study in one of the major problems before this country.

The treatise in very condensed form presents a new plan of attack on stream pollution study and control, by seeking a revision in the basic units and methods now commonly used in this field. By suggesting a unit which may equally well represent the effects of sewage pollution, trade wastes contamination, dilution, self purification, sewage treatment and water purification, the author seeks

[8] Metallurgical Engineer, National Tube Company, Pittsburgh, Pa.
[9] Journal, May, 1921, page 233.

to provide a common denominator for bacteriological, chemical, biological and engineering data, which may make it possible readily to evaluate the combined effects of the above mentioned processes. When it is realized how many costly investigations and programs have been and are now being made or attempted for the study and supervision of the pollution of watercourses, which so regularly prove to be futile and comparatively valueless and leave the problem more vexing and the investigators more discouraged than before, the urgent necessity for a thorough, critical analysis of the accepted methods of approach for these studies cannot be denied.

Stream pollution is a matter of great economic, social and political importance and concerns not only the public health of communities in regard to water supply, bathing and foods, but the safety and operation of manufacturing processes, the uses of water for transportation, for the support of fish life and for purposes of recreation. From the point of view of all these various phases or uses of water, the pollution problem in different locations and at different times has been attacked, but never with more than one or possibly two ideas governing any one investigation. It is this method of trying to solve the problem of the pollution of a stream, by taking into account at any time only one of the major uses of the water courses to the neglect of all the other uses, which has brought stream pollution control to a practical standstill, with the different interests involved generally ready to nullify each other's action. By far the greater portion of the responsibility for this confusing and injurious situation must be placed on the technical, professional leaders and official investigators in this field. Failure to provide a broad and fundamental basis for evaluating the significant qualities which the various interests are concerned in finding and preserving in the water, whereby the sanitarian, the water works bacteriologist, the industrial chemist, and the conservation biologist might see their individual points of view conserved, in my opinion has been no small factor in presenting a true solution of the stream pollution problem. Such a basic unit is courageously urged in the paper of Mr. Wells. At present it seems to fulfill in a measure the requirements for such a unit. At any rate this proposal is certain to prove stimulating in the search for such a standard.

Effective dilution as a unit for pollution values is used as a measure or vector for representing the concentration of pollution constituents having equivalent effects. It is not to be confused with the

terms "direct dilution value" or "dilution required for disposal" as used in problems of sewage treatment. The suggestion of the unit "*effective dilution*" as a pollution basis, as stated in the paper, was presented in Prof. E. B. Phelps' Reports on the Pollution of Boundary Waters for the International Joint Commission. Mr. Wells has enlarged the concept as found in those reports. He is the first to propose it definitely as a common denominator or universal basis for the evaluation of all kinds of pollution concentrations and purification processes. He has arbitrarily established as his zero "effective dilution" the concentration of pollution found in one gallon of water containing the daily wastes of one person. From this point on Mr. Wells shows how a logical system can be developed for representing the effect of dilution of the wastes in the sewer, sewage and trade wastes treatment, river purification, direct dilution, storage and water purification. The principal value of the method lies in the convenience with which it is possible to convert one scale to another, to pass from bacteriological and chemical values to engineering values, from B. coli per liter or dilution positive to effective dilution and then to direct dilution or treatment required. Charts may thus be drawn up, and have already been so prepared with great success by the State Conservation Commission for certain New York Rivers, whereby, on one curve, the pollution values for a stream may be indicated for its entire course, taking into account at the same time the quality at its source, the entrance and extent of the pollution, the addition of direct dilution by tributaries and their pollution concentration, the self purification of the stream, and the quantities of stream flow. It provides a clear graphical presentation of the condition at any point on the stream and the effect of the various processes in operation in the stream. A more intelligent judgment is made possible with the aid of such a chart as to the points on the stream at which earliest control of pollution will be necessary, the condition of the stream for water purification purposes, etc.—in other words, the condition of the stream relative to any quality standards which may be expressed in chemical, bacteriological or engineering units.

Through the possibility of conversion of one kind of data to another, the accuracy of the plot or chart based on one set of data may be checked by securing values for points on the water course from independent data of another kind. One may determine in this way whether a chart for a stream, based on engineering

values, such as population and stream flow statistics, with values obtained for self purification, leads to correct conclusions, by comparing the number of B. coli per liter equivalent to the effective dilution at a point on the stream with the average value based on actual analyses. The entire principle of effective dilution as a measure of pollution may be so readily tested as to serviceability and advantage, that it will probably not be long before its confirmation or rejection as a valuable methodological device will be established.

The rather harsh and stern criticism by Colonel Johnson is so far off the point that it misses altogether the theme of the paper and does a great injustice to the author. It is hoped that the present discussion has shown how incorrect it is to state that "Mr. Wells' basic premise involves the reduction of the pathogenicity of sewage pollution by means of dilution with pure water" that "it is the author's desire to revolutionize the art of water purification." As for the author's statement that "in actual practice sanitarians have arrived at a time factor for storage reservoirs which may be considered the equivalent of safe water purification," which is taken to mean that Mr. Wells stands for purification of water by storage as against purification by filtration of chemicals, a view I feel certain he does not hold, I can grant the critic a conceivable misunderstanding when taking the sentence apart from the rest of the text. That Colonel Johnson should question that such a view actually prevails anywhere is strange, since this very view is made the occasion for his elaborate paper in the JOURNAL.[10] Certainly it must be generally known that the use of storage as a partial equivalent of water purification was long the practice for the city water supply of London, England, where during the war, the coal shortage made curtailment of pumping and consequently of storage advisable and chlorination was instituted. In this country, too, storage is so relied on, perhaps injudiciously, by some of the largest of American cities as an equivalent to treatment, for the protection of their water supplies. But how remote, indeed, is this question from the main theme of Mr. Wells' valuable paper.

SOL PINCUS.[11]

[10] JOURNAL, May, 1921, page 270.

[11] Associate Sanitary Engineer, U. S. Public Health Service, New York, N. Y.

EFFECTIVE DILUTION AS A POLLUTION UNIT

The writer is glad that Mr. Pincus has championed Mr. Wells' cause and has made plain the real purport of the author's paper.[9] He also is in hearty sympathy with Mr. Wells' efforts to provide a reliable basis for determining pollution values.

It is very possible that the writer misunderstood the real point which the author was endeavoring to make in his paper, but if this is so, as Mr. Pincus would have the writer understand, his misconception of the real purpose of Mr. Wells' paper was entirely unintentional, and was occasioned by a considerable degree of cerebral density on the part of the writer or lack of clarity of expression on the part of the author himself; perhaps a modicum of both.

The writer has no desire to be considered unwarrantably guilty of the "severe and unmerited . . . . harsh and stern criticism" whereby Mr. Pincus characterizes his discussion of Mr. Wells' paper. If what the author was driving at was the establishment of certain empirical unit values susceptible of ready use in determining the relative weights of various analytical results, as seems to have been the case, very well and good; but the impression left on the writer's mind after reading the paper through several times was that decided credence was being expressed by the author in the feasibility of dilution to reduce the pathogenicity of human wastes to a plane of consistent reliability comparable with modern water purification practices. Even to suggest such a thing was to the writer's mind entirely wrong and deserving of prompt and unmistakable challenge.

The writer submits in all modesty that if he himself got the wrong idea when reading the paper many city officials would be similarly misled, and perhaps become willing converts to the dilution idea because of the expense thus avoided for building water and sewage purification plants. Such doctrines cannot properly be advanced even in a suggestive way, and this single point would in a considerable measure seem to merit the adverse comments made by the writer on Mr. Wells' paper.

There is no such thing as *Effective Dilution* in the sense that dilution alone can be relied upon continuously and consistently to render impure water pure and hygienically safe. The term is an unfortunate one. From what Mr. Pincus has to say it would seem that

Mr. Wells had no such idea in mind when preparing his paper. If so the writer missed the author's main point altogether. The writer is in favor of any efforts made to standardize and improve analytical methods and their interpretation, but he is utterly opposed to any proposition which will mislead the public into the conviction that all it has to do is to locate a big enough body of water and into it discharge its sewage, leaving to simple dilution the cardinally important duty of nullifying satisfactorily the nuisance of that sewage and its constant potential pathogenicity.

George A. Johnson.[12]

THE WASTE OF WATER IN DETROIT[13]

Since the presentation of the paper by Mr. Fenkell at the Cleveland Convention, June 7, 1921, a careful examination has been made of the consumption and waste of water in a residential section of the better class, in Detroit.

Description of section investigated. The section of the city selected for this investigation was bounded on the north by Joy Road, on the east by Linwood, on the south by North Grand Boulevard, and on the west by Grand River. It covered approximately two-thirds of a square mile in surface area, contained approximately 13.9 miles of 6-, 8-, and 10-inch pipe, and housed 12,884 people, who were supplied with water through 2458 service connections.

The dwellings were practically all of brick construction and the majority of them housed two families. There were 2 eight-apartment buildings, 2 six-apartment buildings, and 6 four-apartment buildings. There was one public school and one church with school attached. It is thus seen that there was practically a total absence of commercial consumption of water.

Method of procedure. A 10-inch water main runs north and south through the center of the section with 6- and 8-inch laterals. Valves on the boundary lines of the section were closed so that water from one point only could enter, and a Pitometer was placed at the point of entrance of the water. Seven Pitometer measurements were made for periods of 24 hours each, showing the varying rates of flow of water and the total consumption for each period. A normal pressure was maintained throughout the measurements.

[12] Consulting Engineer, 150 Nassau Street, New York, N. Y.
[13] This Journal, page 583.

During one of these measurements, that of June 28 and 29, 1921, a sufficient number of meter readers were put in the section to read all the meters in one day. The following day another reading was taken on each meter, in the same order as on the previous day, and as nearly as possible 24 hours after the first reading. In cases where the occupant was out, an estimate of the consumption was arrived at by an examination of the records of previous metered consumption. In the case of a few places that were not metered, the consumption was arrived at by determining the number of occupants with the number and condition of the plumbing fixtures.

There were 1984 meters read for a total of 65,261 cubic feet, 463 meters were estimated to register 14,276 cubic feet, and 11 unmetered places were estimated to have a consumption of 267 cubic feet. All of the above items of consumption were increased 5 per cent to correct for under-registration of meters.

An examination of the accompaning charts showing the varying rates of flow of water into this section, indicates that the minimum or lowest rate of flow obtains from 2 a.m. to 3 a.m. An effort to obtain the exact distribution of this minimum night flow over the various blocks would of a necessity have limited the work to these hours. Because of the number of blocks involved, the investigation of the distribution of the night flow was carried on between the hours of midnight and 5 a.m.

This gives a sum total of the block night rates somewhat in excess of the indicated minimum night rates on the chart, but it is believed that no serious error has been introduced in the study of conditions existing in the individual blocks. The section was divided into 77 parts to determine the allocation of the minimum night rate of flow.

A thorough inspection was then made of the condition of the plumbing fixtures in all premises, tests made to determine the presence of leakage on service connections, and a census of the occupants of each building. The inspectors made records of the nature, location, and amounts of water wasted by the fixture leakage. The amount of waste was arrived at by watching the registration on the meter for a period of five minutes after having previously requested the occupants to refrain from using water during the inspection. It is worthy of special mention that out of the 2458 service connections inspected for leakage, all but two were found to be tight.

Variations in consumption. The five charts submitted which show the rates of flow in the section under discussion, are of more than usual interest for several reasons:

Chart 1 showing the rate of flow, starts at 4 p.m., June 20, 1921. This was a very hot muggy day, the temperature being 83° at 4 p.m., 77° at 8 p.m., and 68° at midnight. The rate of flow at 4 p.m. was 1,200,000 gallons per 24 hours, at 8 p.m. when the lawn sprinkling was at its height, this had increased to 2,100,000, and 4 hours later or at midnight had dropped to 560,000, the lowest rate (335,000) being reached at 4 a.m. when the temperature was 70°. The following morning the weather was clear with an increased humidity, the temperature rising from 70° at 4 a.m. to 73° at 8 a.m. and reaching a peak of 90° at 1 p.m. The rate of flow increased from 335,000 gallons at 4 a.m. to 1,650,000 gallons at 8 a.m. Soon after 8 a.m. the weather became cloudy with indications of an approaching storm, and a consequent reduction in lawn sprinkling resulted. This reduction was gradual until noon, and from then until 3 p.m. it was very rapid, going as low as 860,000 gallons. About 1 p.m. there was a severe electrical storm accompanied by a cloudburst and this resulted in practically no sprinkling on the evening of June 21. An interesting comparison between the sprinkling load on a hot dry day and on a day following a heavy rain is thus obtained. At 8 p.m. the hot day, the rate of flow was 2,100,000 gallons and at 8 p.m. on the following day was 1,390,000 gallons or approximately 35 per cent less.

Chart 2 shows the rate of flow from 8 a.m., June 28, to 8 p.m., June 29, 1921; this was the period during which the meter readers were securing data on the metered consumption. The highest temperature was 79° on the morning of June 28, and the lowest was 69° at 7 a.m., June 29. There was slight precipitation, there being a light shower from 4 to 5 p.m., June 28.

Chart 3 shows the rate of flow for three consecutive days, September 14, 15, and 16. The maximum temperature was 81° at 6 p.m. on September 14, and the minimum was 59° at 4 a.m. on September 16. There was practically no precipitation during these days and temperatures were possibly a trifle above normal, but on the whole they were typical fall days. The point of particular interest in this chart is the marked similarity in the rates of flow for the different days.

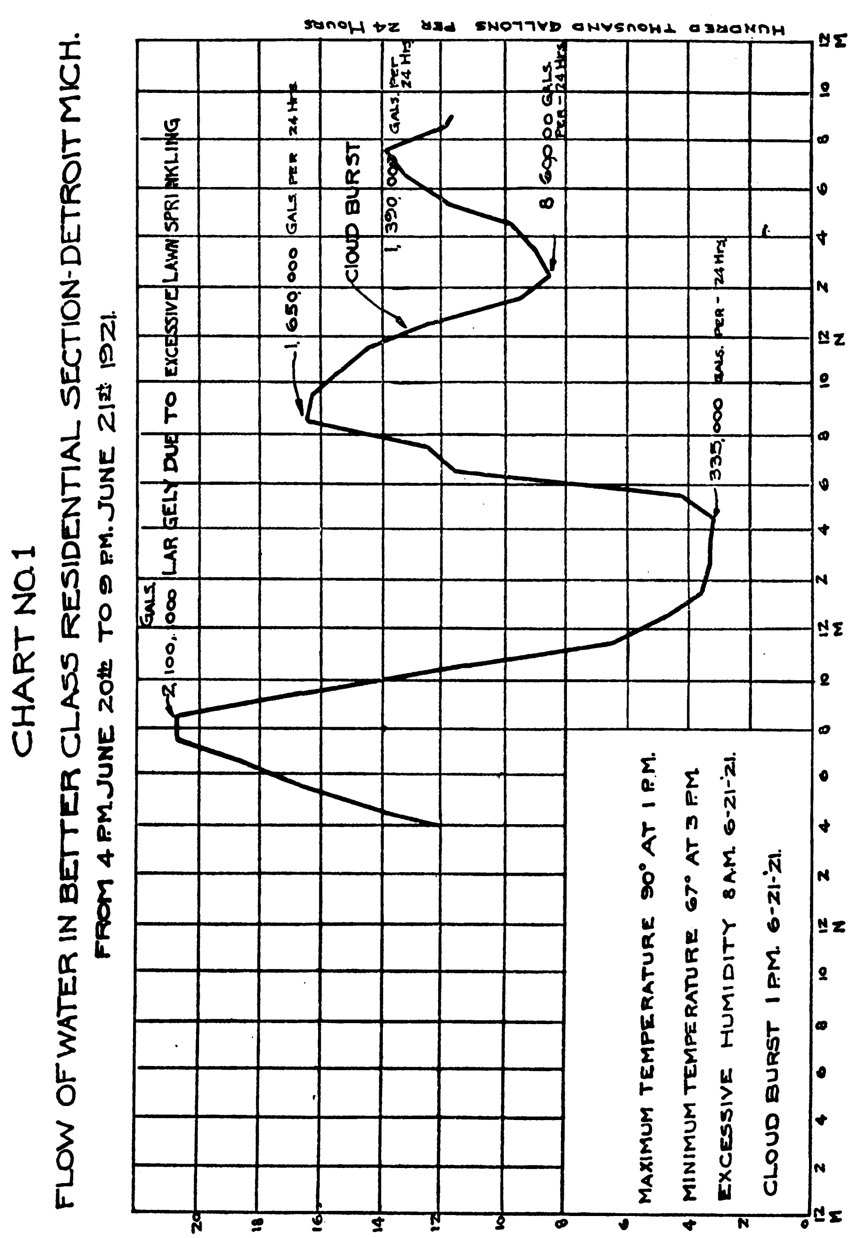


CHART NO. 1
FLOW OF WATER IN BETTER CLASS RESIDENTIAL SECTION-DETROIT MICH.
FROM 4 P.M. JUNE 20th TO 9 P.M. JUNE 21st 1921.
HUNDRED THOUSAND GALLONS PER 24 HOURS
LARGELY DUE TO EXCESSIVE LAWN SPRINKLING
2,100,000 GALS.
1,650,000 GALS PER 24 Hrs
CLOUD BURST
1,390,000 GALS. PER 24 Hrs
335,000 GALS. PER - 24 Hrs
MAXIMUM TEMPERATURE 90° AT 1 P.M.
MINIMUM TEMPERATURE 67° AT 3 P.M.
EXCESSIVE HUMIDITY 8 A.M. 6-21-21.
CLOUD BURST 1 P.M. 6-21-21.

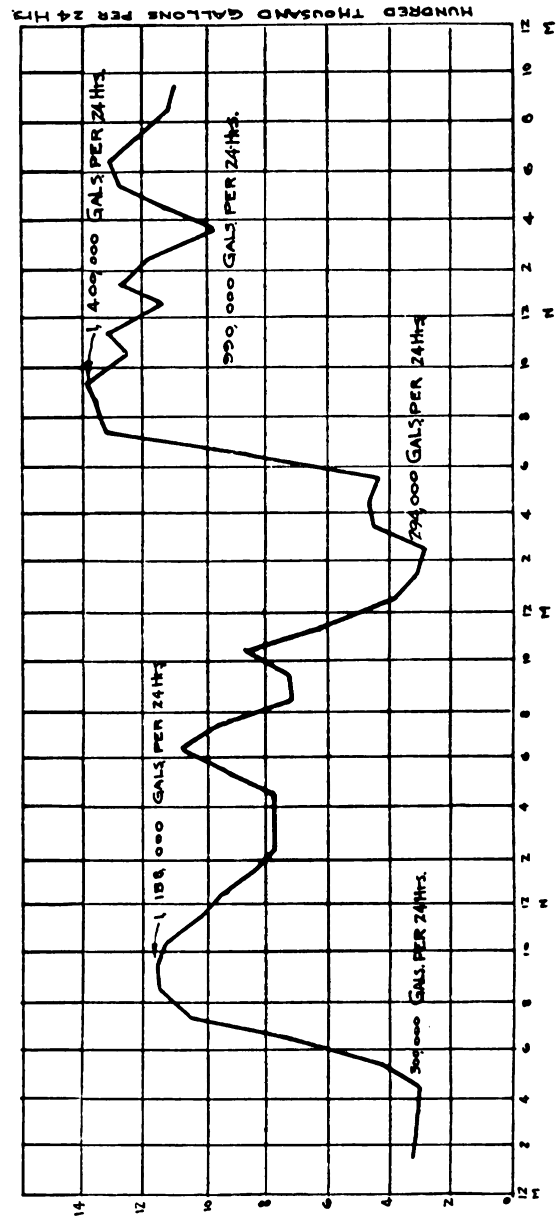


CHART NO. 2

FLOW OF WATER IN BETTER CLASS RESIDENTIAL SECTION DETROIT MICH.

FROM 1 A.M. JUNE 28th TO 10 P.M. JUNE 29th 1921

MAXIMUM TEMPERATURE 84° AT 3 P.M. JUNE 29th

MINIMUM TEMPERATURE 65° AT 7 A.M. JUNE 29th

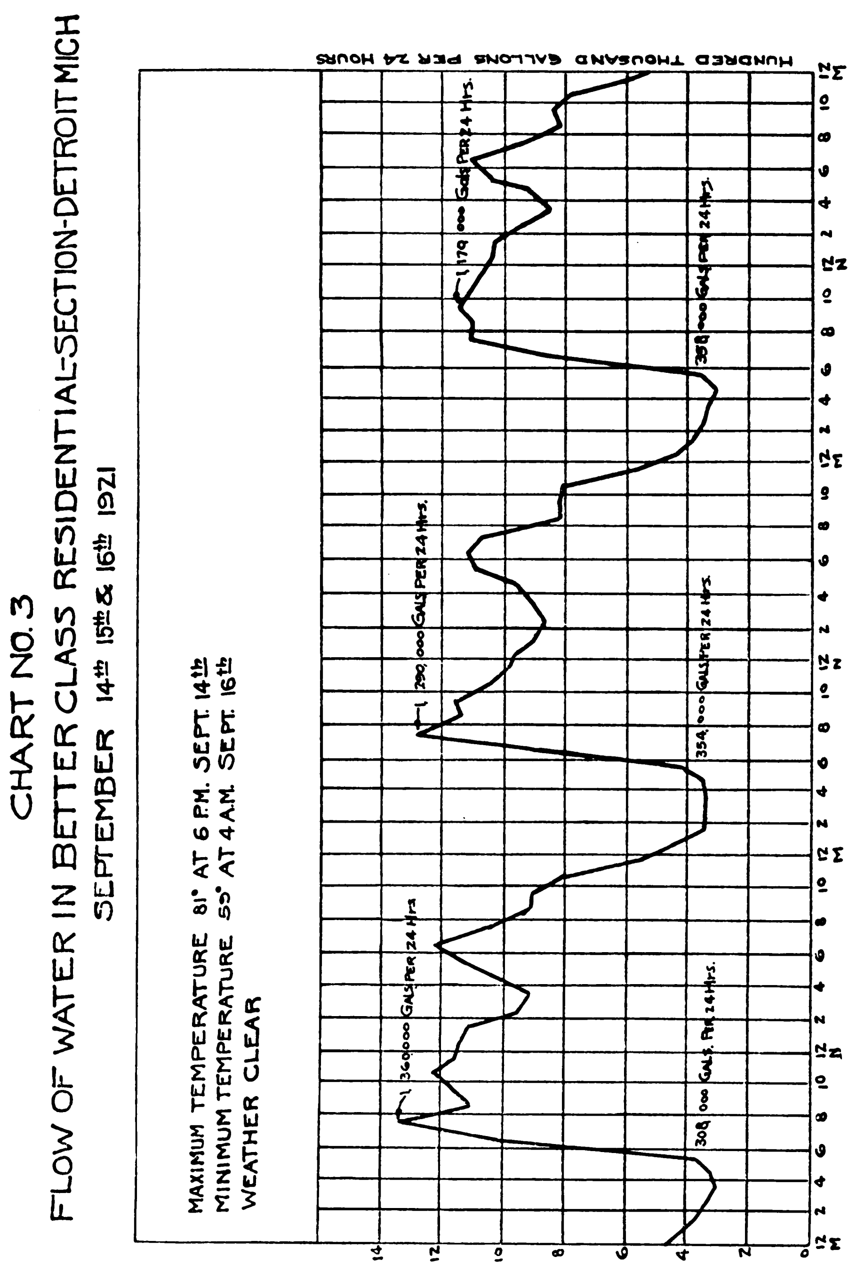


CHART NO. 3
FLOW OF WATER IN BETTER CLASS RESIDENTIAL-SECTION-DETROIT MICH
SEPTEMBER 14th 15th & 16th 1921
MAXIMUM TEMPERATURE 81° AT 6 P.M. SEPT. 14th
MINIMUM TEMPERATURE 55° AT 4 A.M. SEPT. 16th
WEATHER CLEAR
HUNDRED THOUSAND GALLONS PER 24 HOURS
1,360,000 GALS PER 24 Hrs
308,000 GALS. PER 24 Hrs.
1,290,000 GALS PER 24 Hrs.
354,000 GALS PER 24 Hrs
1,179,000 GALS PER 24 Hrs.
358,000 GALS PER 24 Hrs

Chart 4 shows the rate of flow for October 1, 15 days later than the previous chart, and is of interest because of the marked similiarity to the preceding chart; the rates of flow being somewhat less and the temperature being approximately 11 degrees lower.

Chart 5 shows the rates of flow for October 12, 1921. It will be noticed that this chart has the same general characteristics as the two preceding ones; the temperature being practically the same.

It is not frequently found convenient to secure charts showing the varying rates of flow in any one section at different seasons of the year, and where the internal conditions of the section vary as little as in this one. These charts would therefore seem to be of unusual interest.

Investigation of use and waste. From 8 a.m., June 28, to 8 a.m., June 29, 1921, the consumption and waste of water in this section amounted to 786,000 gallons. Since there were 12,884 people in this section, this is equivalent to a per capita consumption from all causes of 61.06 gallons. The 786,000 gallons just mentioned contained items of underground leakage (20,000), street sprinkling (10,266), and the use of water in public buildings (5250) amounting to 35,516 gallons. When this amount is subtracted from 786,000 gallons the per capita consumption becomes 58.31 gallons.

Mr. Fenkell states in his paper that the average per capita consumption per day, determined by venturi meter measurement from July 1, 1920, to April 30, 1921, was 144.50 gallons. This figure contains many items not included in the section under discussion and if we subtract from the gross per capita consumption (144.50) the per capita values of the quantities which do not enter into this section as shown below, we find we have left 60.53 gallons as against

Consumption of water in Detroit

		GALLONS PER CAPITA PER DAY	
		Mr. Fenkell	Special test section
From all sources	144.50		58.31
Commercial		49.40	
Villages		13.15	
Municipal		17.44	
Water Works		3.98	
	83.97		
	60.53	83.97	58.31

CHART NO. 4

FLOW OF WATER
BETTER CLASS RESIDENTIAL SECTION
DETROIT, MICH.

MAXIMUM TEMPERATURE SEPT. 30th 68° AT NOON

MINIMUM TEMPERATURE SEPT. 30th 58° AT 6 A.M.

SEPTEMBER 30th 1921

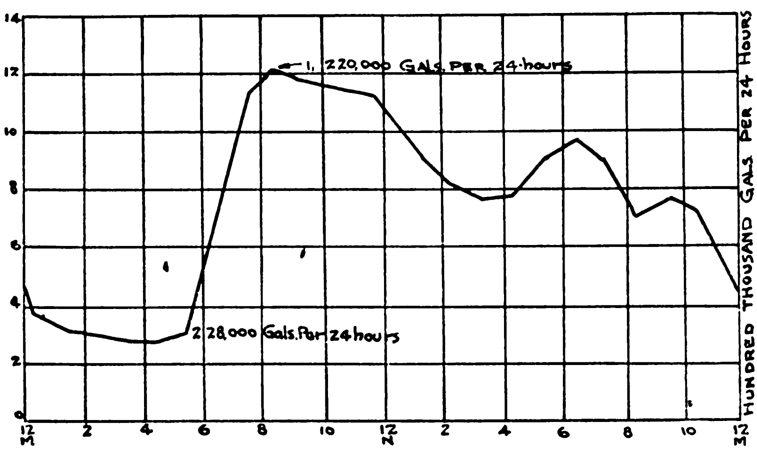
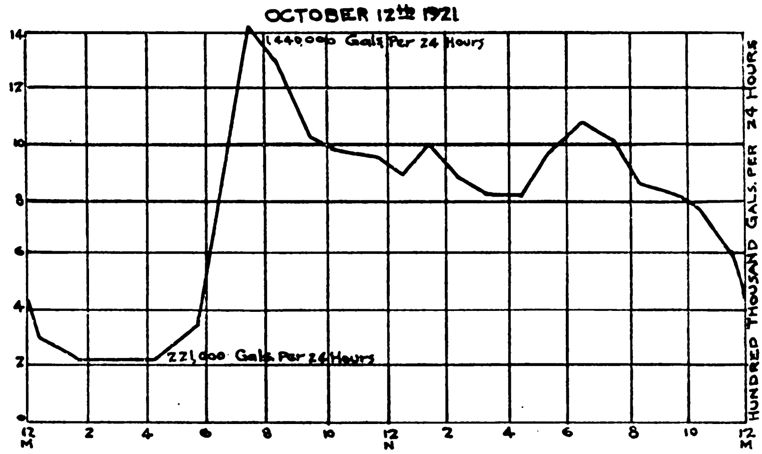


CHART NO. 5

WEATHER-AVERAGE FALL DAY

OCTOBER 12th 1921



our per capita figure just mentioned, 58.31 gallons, or approximately $2\frac{1}{4}$ gallons discrepancy.

There were found 917 defective plumbing fixtures to waste 211,031 gallons per day, or at the average rate of 230 gallons per fixture per day. This is considerably less than the 977 gallons loss per leaking fixture as mentioned in Mr. Fenkell's paper. This is not surprising, for as stated by Mr. Fenkell, in the general procedure of the survey in many blocks where the night consumption was reasonable, no house to house inspection was made. In the investigation of this special section, all premises were inspected regardless of the amount of the night consumption. This section contained no old dwellings and there is a much lesser tendency toward leaking fixtures in new dwellings than in old.

As stated in the preceding paragraph, the waste by fixture leakage is believed to be 211,031 gallons and with 12,884 people in the section, this becomes 16.38 gallons per capita for fixture leakage. This compares with 22.33 gallons as was determined by Mr. Fenkell, and it is believed that his figure is nearer a fair average for Detroit than the one just submitted, for generally the class of people living in the special test section would not allow a bad fixture to waste water for any long period of time.

In the special test section it was found:

	gallons
2445 domestic metered accounts gave a per capita consumption...	48.20
11 domestic flat rate accounts gave a per capita consumption...	0.16
	48.36

We have already shown that the item of fixture leakage amounts to 16.38 gallons per capita. If we accept as reasonable Mr. Fenkell's data on the amounts to be charged to lawn sprinkling (0.90) and carelessness (1.50), we have as the total amount of preventable domestic use and waste 18.78 gallons. Subtracting this from the 48.36 gallons just mentioned, we have left as the amount chargeable to legitimate domestic use 29.58 gallons per capita. This compares with 25.23 gallons as found by Mr. Fenkell, and would seem to substantiate his figure very well, as his estimate covered all types of dwellings and all classes of people, whereas this rate applies to one particular class only.

At the time of the 24-hour measurement of this section, the lowest rate of flow was 294,000 gallons or 22.82 gallons per capita. If we

subtract from the 294,000 gallons the amount of water wasted by fixture leakage, 211,031 gallons, we have left as a net per capita night rate consumption from all other causes 6.44 gallons. This would appear to be very low, but if we bear in mind that the lowest rate of flow is in force for a very short period of time at night, this figure does not seem improbable.

As stated on a previous page, the investigation as to the distribution of the night rate over the entire section was carried on between the hours of midnight and 5 a.m., and this would ordinarily be the period during which the night rate of domestic use of water would be in force. The total amount of the night rate investigation was 459,850 gallons and if we subtract from this the amount of fixture leakage, we have left a per capita night rate of 19.31 gallons which checks very closely the figure of 22 gallons as given by Mr. Fenkell.

Very little underground leakage was found in this section. This condition is not surprising for the water mains have been laid for a comparatively short period of time. The absence of street car tracks would make it seem probable that there was practically no electrolysis. There is an absence of heavy trucking over the streets, reducing the leakage due to vibration. The character of the soil, an impervious blue clay, would have a tendency to send water from any leak of consequence to the surface. Two small hydrant leaks and two service leaks were found wasting water at a total estimated rate of 20,000 gallons per day.

In spite of the facts mentioned in the preceding paragraph, it does not seem probable that the piping system is bottle tight, for when we stop to think that there are 440 lead joints in a mile of straight pipe laying, and that this number is considerably increased by the introduction of the necessary specials for valves, hydrants, and street intersections, it would seem that there must be some small item of joint leakage. We believe that a conservative estimate for this section is 3000 gallons per mile of pipe per 24 hours. Since there are 13.9 miles of pipe in the section, this item becomes 41,700 gallons per 24 hours or a per capita rate of 3.23 gallons which compares with 2.44 gallons as shown in Mr. Fenkell's paper. This per capita rate would vary of course with the density of the population, being less as the population increases. It would seem, therefore, that Mr. Fenkell's estimate is about correct.

Summary. The item of 786,000 gallons of water which was consumed or wasted in this section, appears to be divided into the following items:

	GALLONS PER 24 HOURS	PER CAPITA PER 24 HOURS
Metered consumption	633,733	49.23
Underground leakage (actual)	20,000	1.55
Unavoidable underground leakage (estimated)	41,700	3.24
Street flushing	10,266	0.80
Unaccounted for	80,301	6.24
	786,000	61.06

Many authorities disagree as to what percentage of the lowest rate of flow of water supplied any community is actually legitimate domestic use. It would seem that this would vary greatly with the character of the population, and in the section we have just been discussing, it is interesting to note that it appears to be less than 8 per cent of the lowest rate of flow. This conclusion is arrived at in the following manner:

	gallons
Fixture leakage	211,031
Actual underground leakage	20,000
Estimated, unavoidable, underground leakage	41,700
	272,731

272,731 gallons divided by 294,000 gallons, which is the minimum night rate of flow, gives as the percentage of the night flow wasted, 92.8 per cent. This would seem to leave but 7.2 per cent of the water for domestic use. Our records show that the street flushing did not occur at the time of the minimum night flow.

Following are the tabulated results of the sums of the items as shown by block investigation. From this it will appear that the gross per capita consumption for this section is 53.98 gallons, that the net per capita per day consumption is 31.81 gallons, that the gross per capita night flow is at the rate of 35.69 gallons per 24 hours, and that the net per capita night use of water is at the rate of 14.51 gallons per 24 hours.

It also appears that there are 5.2 persons per service, that the average daily consumption from all causes per service is approxi-

mately 320 gallons, and that the minimum night rate of flow per service is approximately 120 gallons.

Average daily consumption		786,000 gallons
Minimum night rate		294,000 gallons
Subdivision night rate		459,850 gallons
Lineal feet of pipe		73,360
Allowable leakage (3000 gal. per mile of pipe per 24 hours)		41,828 gallons
Underground leakage:	*Number*	*Amount*
Defective service connections	2	10,000 gallons
Defective hydrants	2	10,000 gallons
	4	20,000

Net amount of night rate charged to legitimate, domestic consumption and fixture leakage	390,022 gallons
Population	12,884
Total number of places listed	2,458
Number metered	2,447
Number unmetered	11
Number of places metered O.K. (no fixture leakage)	1,923
Number of places metered with fixtures leaking	524
Number of unmetered places O.K. (no fixtures leaking)	9
Number of unmetered places with fixtures leaking	2
Actual and estimated leakage on 677 fixtures	209,111 gallons per day
Estimated leakage on 240 dripping fixtures	1,920 gallons per day
Total estimated and actual amounts of water wasted by fixture leakage	211,031 gallons per 24 hours

Detail of fixture leakage:

Faucets	337
Toilets	318
Miscellaneous	22
Drips	240
Total	917

Gross consumption per day:

Actual metered	65,261 cu. ft.	1,984 services
Estimated metered	14,270 cu. ft.	463 services
Estimated not metered	267 cu. ft.	11 services
	79,804 cu. ft.	2,458 services
Plus 5 per cent for meter slip	3,990 cu. ft.	
Grand total	83,794 cu. ft. or 633,733 gallons per 24 hours	

Gross per capita consumption	53.98 gallons per day
Net per capita consumption	32.81 gallons per day
Gross per capita night rate	35.69 gallons per day
Net per capita night rate	14.51 gallons per day

Comparison of the results shown in this investigation with those of Mr. Fenkell's:

	Gallons per capita per day	
	This investigation	Mr. Fenkell's
Domestic:		
2445 Metered accounts	48.20	46.48
11 Flat rate accounts	0.16	4.23
Service connection leaks	0.77	5.45
	49.13	56.16
Municipal (only such of these items compared as appear in the section investigated):		
Sprinkling and flushing streets	0.79	0.53
1 Public school*	0.31	3.01
1 Private school*	0.097	0.55
	1.197	4.09
Water Works:		
Leaks in mains	0	3.26
Flushing mains	0	0.72
	0	3.98
Minimum night domestic consumption	19.31	22.00
Fixture leakage	16.38	22.33
Unavoidable underground leakage	3.23	2.44
The estimate of the daily consumption will now appear as follows:		
1. To prevent freezing	0	0.75
2. Lawn sprinkling (estimated)	0.90	0.90
3. Leaks in service connections	0.77	5.45
4. Leaks in fixtures	16.38	22.33
5. Carelessness	1.50	1.50
	19.55	30.93

* At the time of the special investigation the schools were not in session.

Subtracting 19.55 from the total domestic consumption as shown by this investigation (49.13), we have left 29.58 gal. for domestic use. Subtracting 30.93 from the total domestic consumption (56.16), as shown by Mr. Fenkell, we have left 25.23 gallons for domestic use. This comparison then becomes 29.58 against 25.23 as the amount of legitimate domestic consumption.

Wm. A. Jones.[14]

[14] Assistant Engineer, Pitometer Co., Water Board Building, Detroit, Mich.